Modeling Navigation Conditions at Lock Approaches

Richard Stockstill & Charlie Berger

Coastal & Hydraulics Laboratory

Mark Hopkins

Cold Regions Research Engineering Laboratory

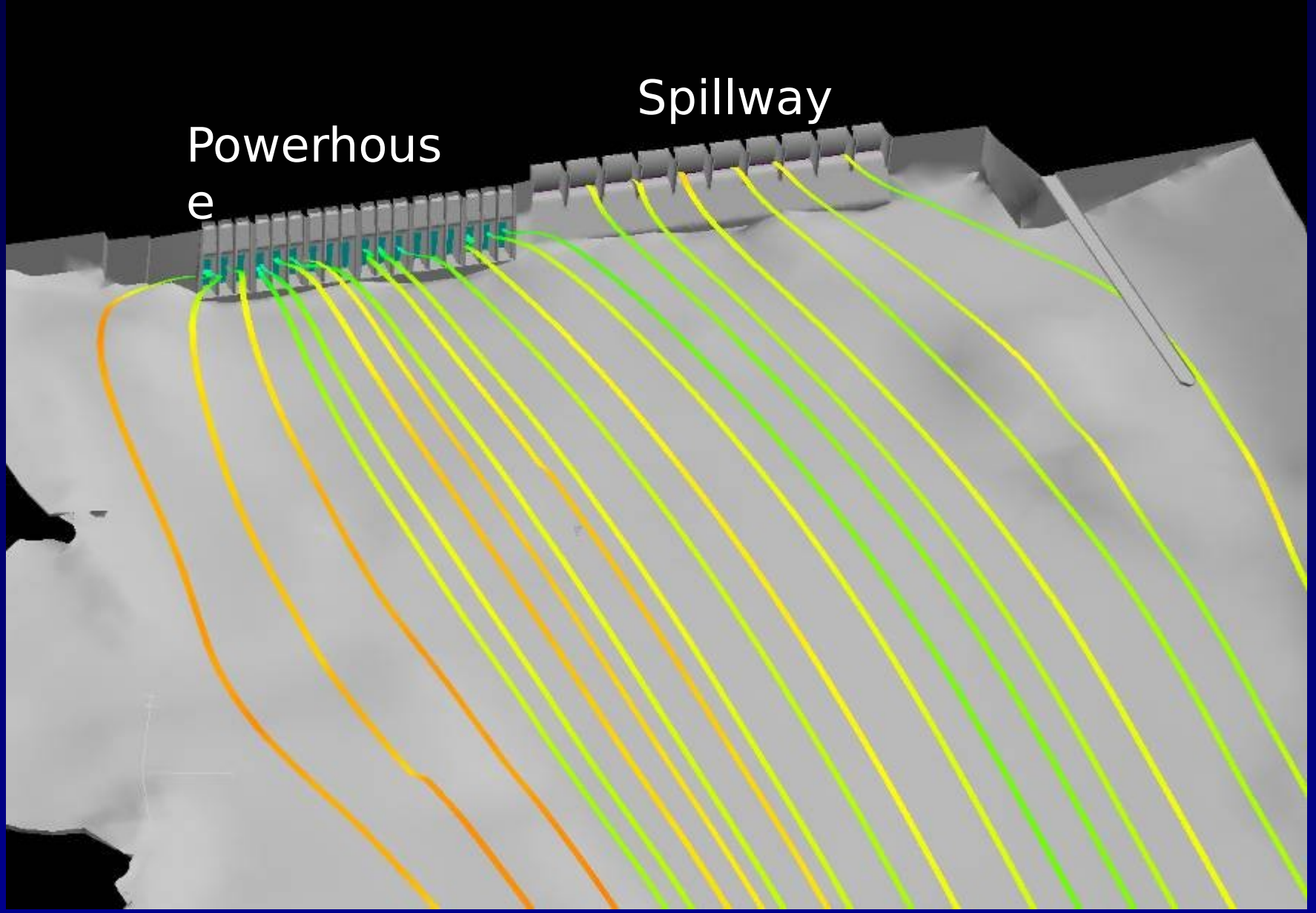
US Army Engineer Research & Development Center

US Army Corps of Engineers®

ERDC

Modeling Considerations

- Flow Conditions must be accurate.
- Vessel/flow interaction must be coupled.
  - Loose Coupling
  - Tight Coupling
- Pilot input must be included.
  - Real time response
  - Effect on vessel/flow interaction



US Army Corps of Engineers®

Ice Harbor Dam

Streamlines

ERDC

Couple Discrete Element Model (DEM) Capabilities with Adaptive Hydraulics (ADH) Model

- Coupling of ADH and DEM to model ice and debris at CoE locks = feed-back from DEM to ADH and vice versa
- Integrate many aspects of CoE navigational, structural, and hydraulic modeling. (Ice and debris mitigation, tows, guard walls, gates, lockage, barge impacts, hydraulics)

US Army Corps of Engineers®

ERDC

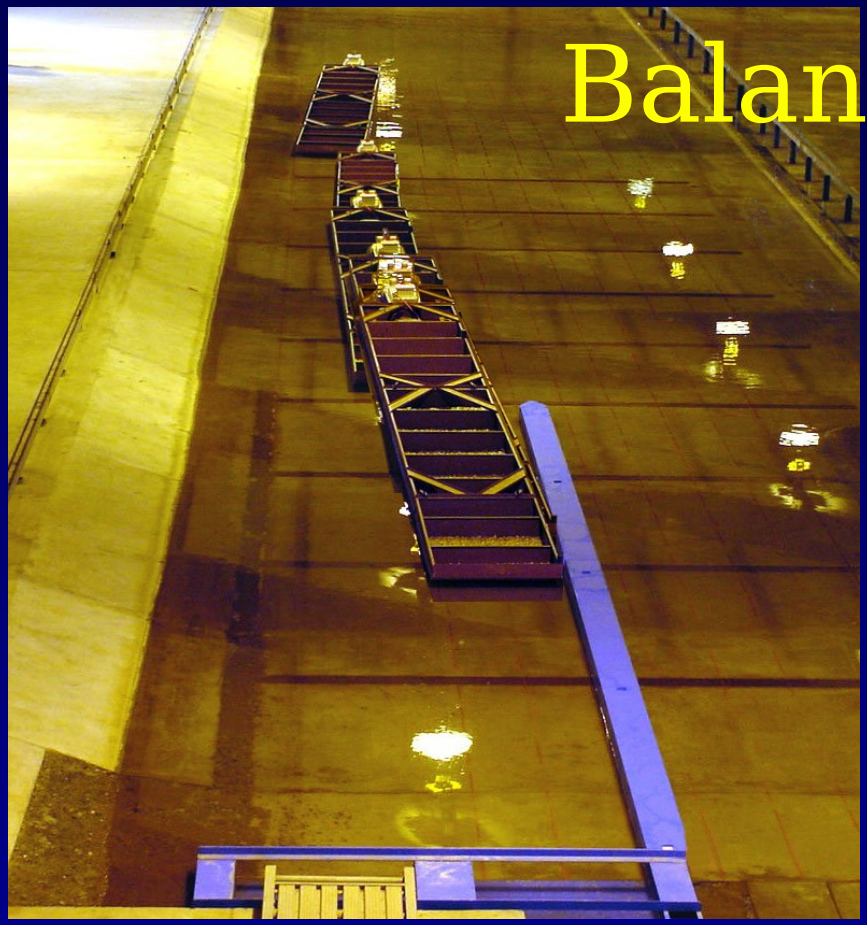
Couple DEM Structural Capabilities with Flow Solutions of ADH

- Provide the CoE with a unique modeling ability to address fluid/structure interactions.
- Simulate placement of emergency lock bulkheads and dam gates. Calculate hydraulic forces during placement.
- Simulate placement of float-in lock components.

Products

- Coupled ADH/DEM code to simulate fluid/structural interaction at CoE locks and dams.
- DEM structural modules integrated into ADH.
- Detailed model study of emergency placement of a bulkhead to replace a failed lock gate.

Guard Wall Design is a Balancing Act



Balance Outdraft and Draw Toward the Wall

- Flow around the wall vs. impact on the wall
- Minimize both

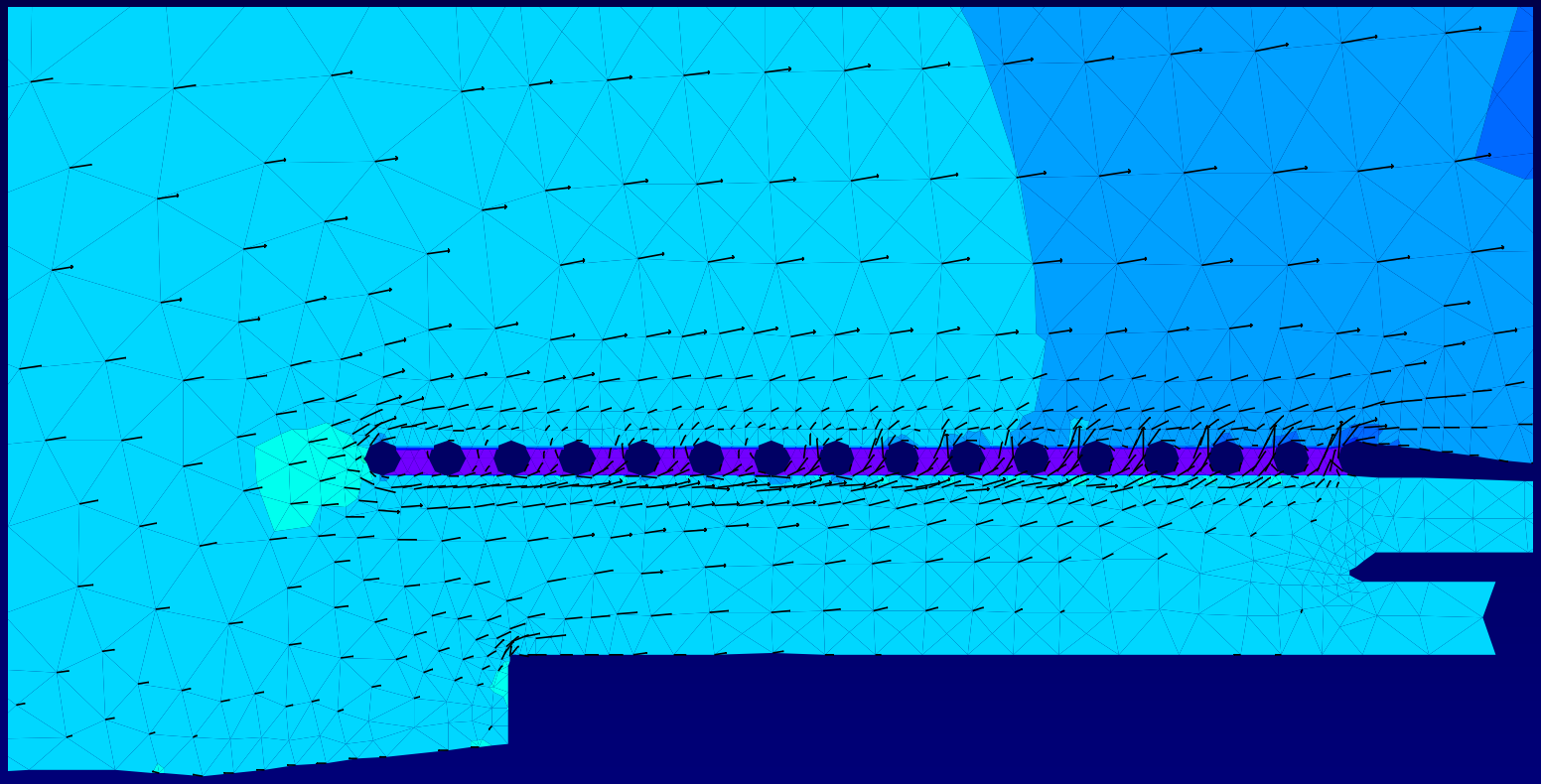
US Army Corps of Engineers®

ERDC

Skirted Guard Wall

US Army
Corps
of Engineers®

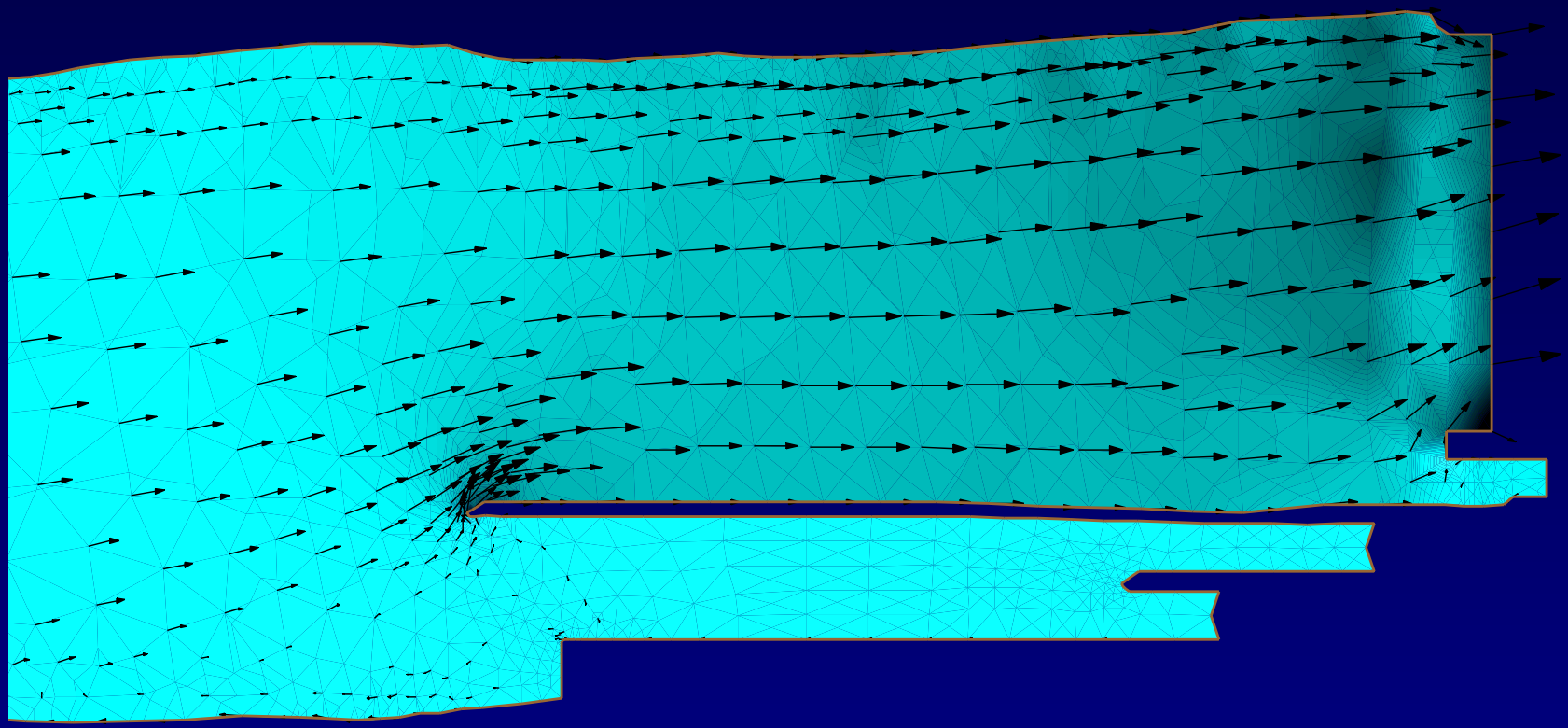
ERDC
Engineer Research and Development Center
Vicksburg Internet



Multicell Guard Wall

US Army
Corps
of Engineers®

ERDC
Engineer Research and Development Center
Vicksburg Intranet



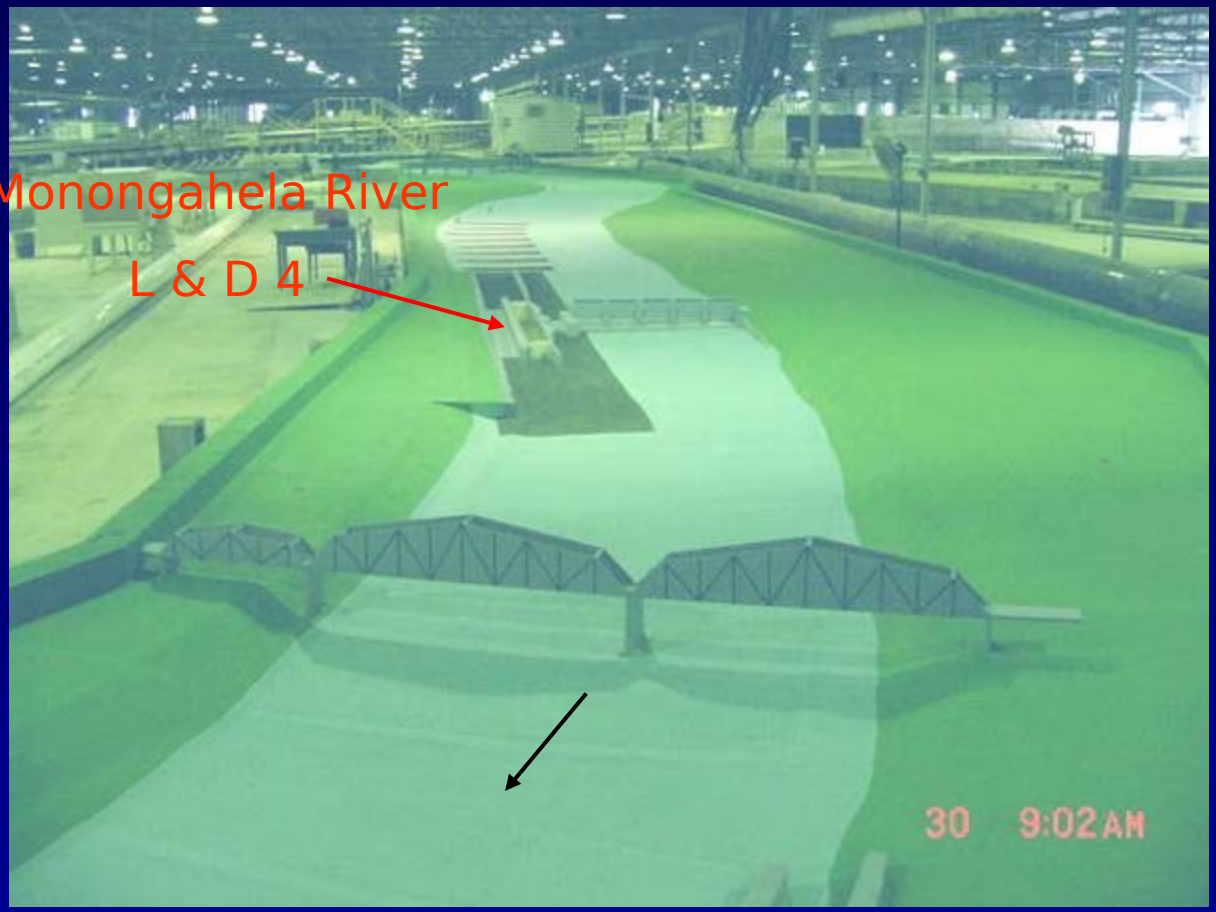
Monongahela River L & D 4

Existing Conditions

US Army
Corps
of Engineers®

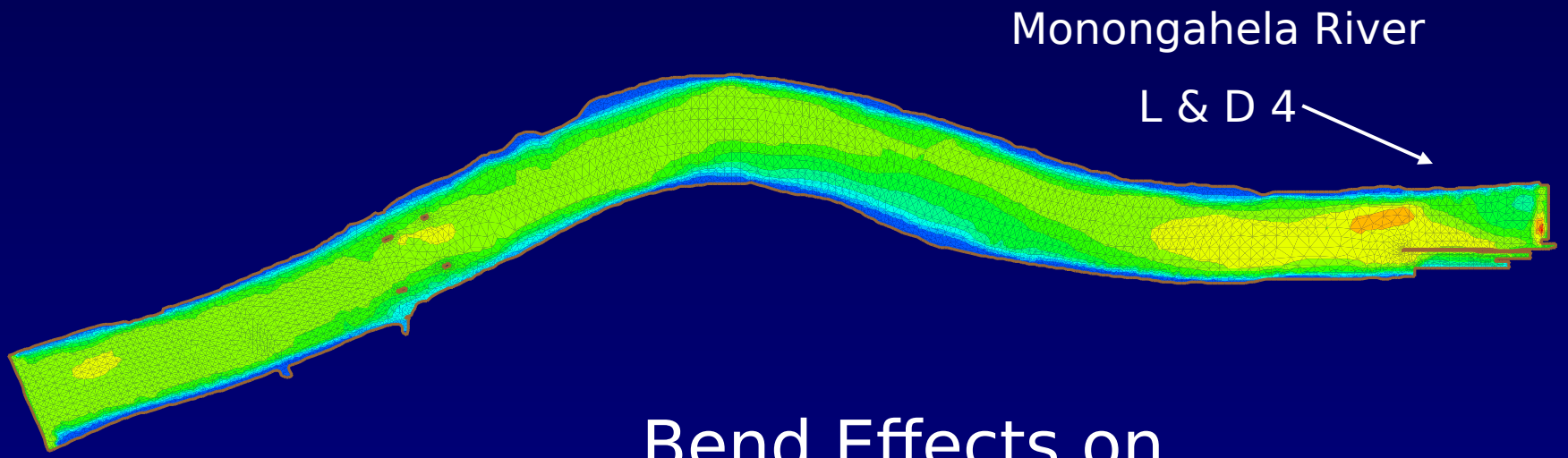
ERDC
Engineer Research and Development Center
Vicksburg Internet

Lock Downstream of River Bend



US Army Corps of Engineers®

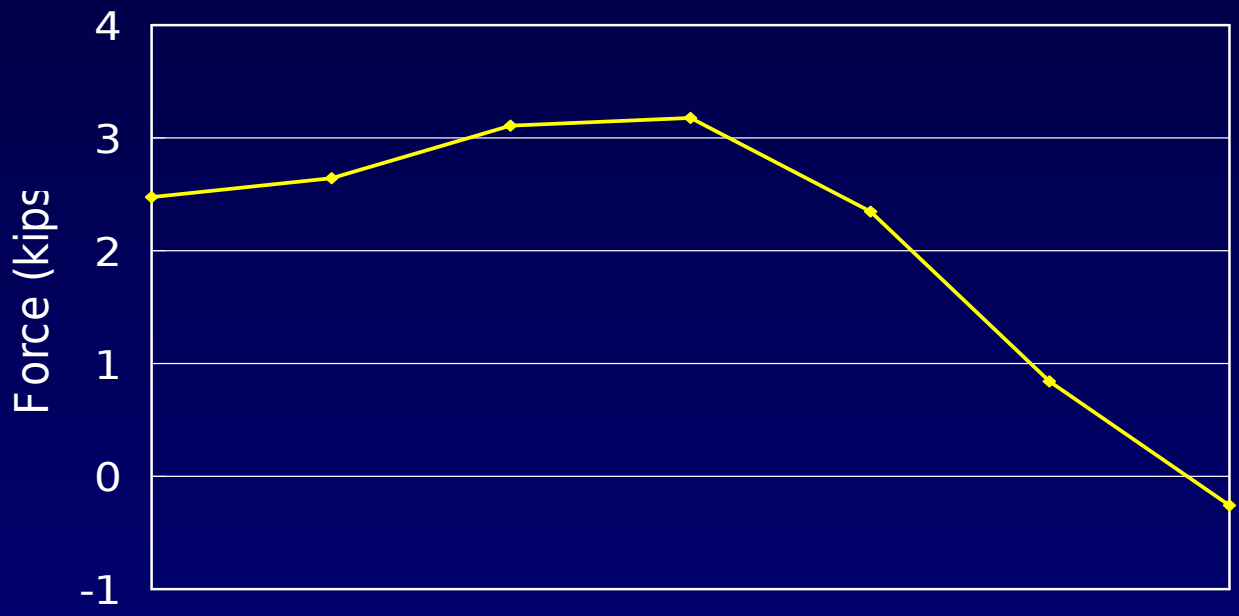
ERDC
Engineer Research and Development Center
Vicksburg Internet

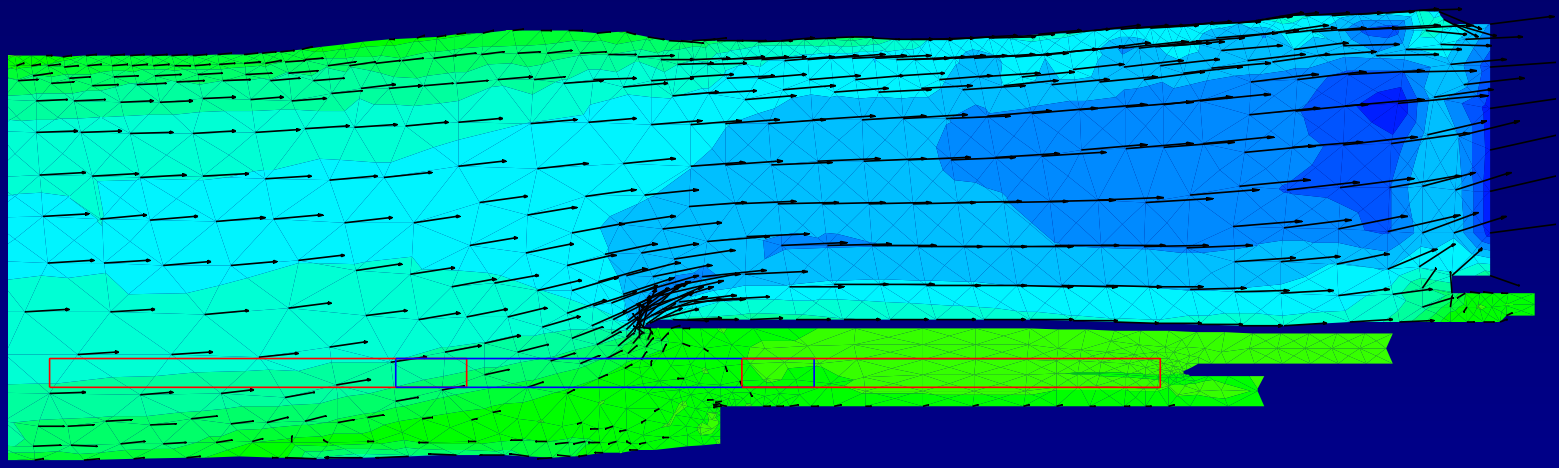


Bend Effects on Lock Approach

US Army Corps of Engineers®

ERDC
Engineer Research and Development Center
Vicksburg Internet



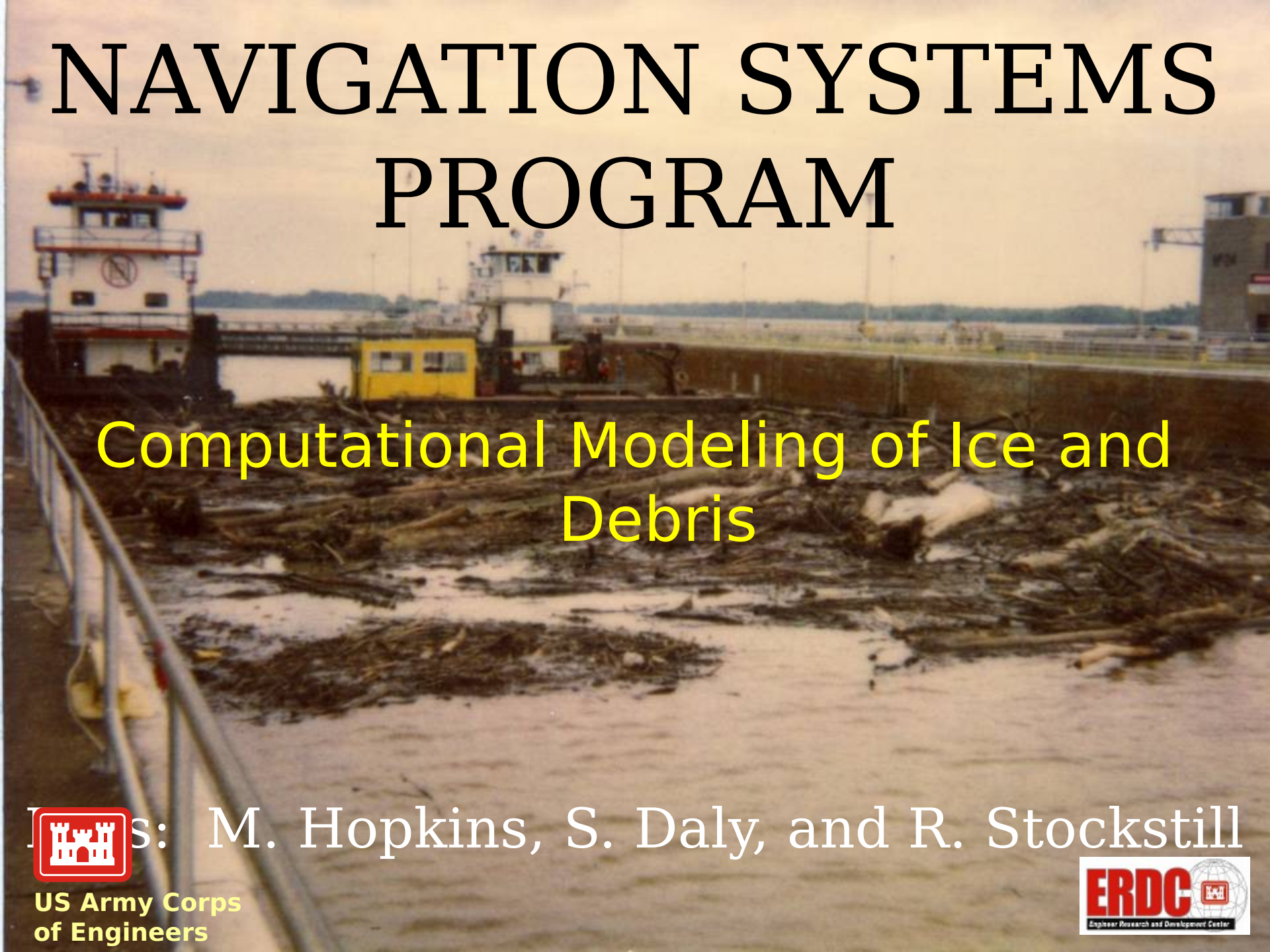


Computing Outdraft from Hydro Model

US Army Corps of Engineers®

ERDC

NAVIGATION SYSTEMS PROGRAM



Computational Modeling of Ice and Debris

Authors: M. Hopkins, S. Daly, and R. Stockstill

US Army Corps of Engineers

ERDC Engineer Research and Development Center

PROBLEM

Debris accumulation at locks and dams

US Army Corps of Engineers®

ERDC
Engineer Research and Development Center
Vicksburg, Mississippi

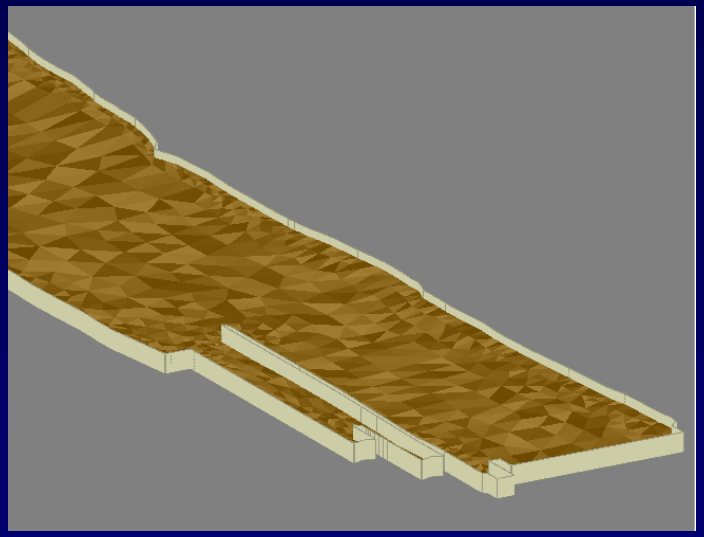
PROBLEM

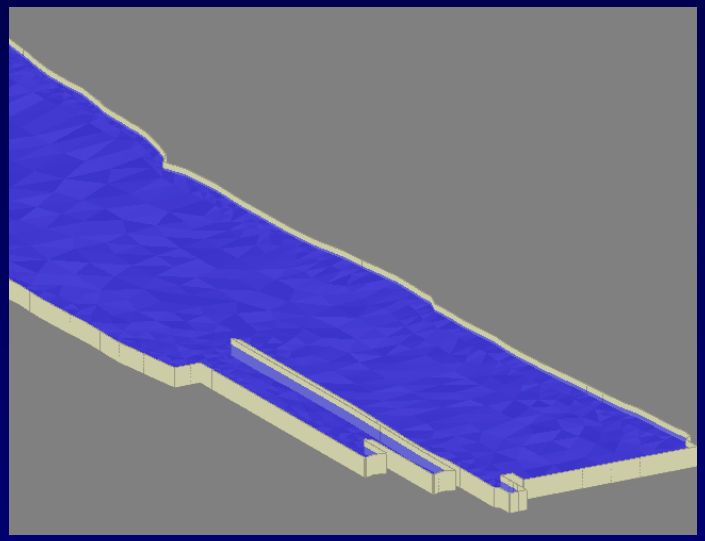
Ice accumulation at locks and dams

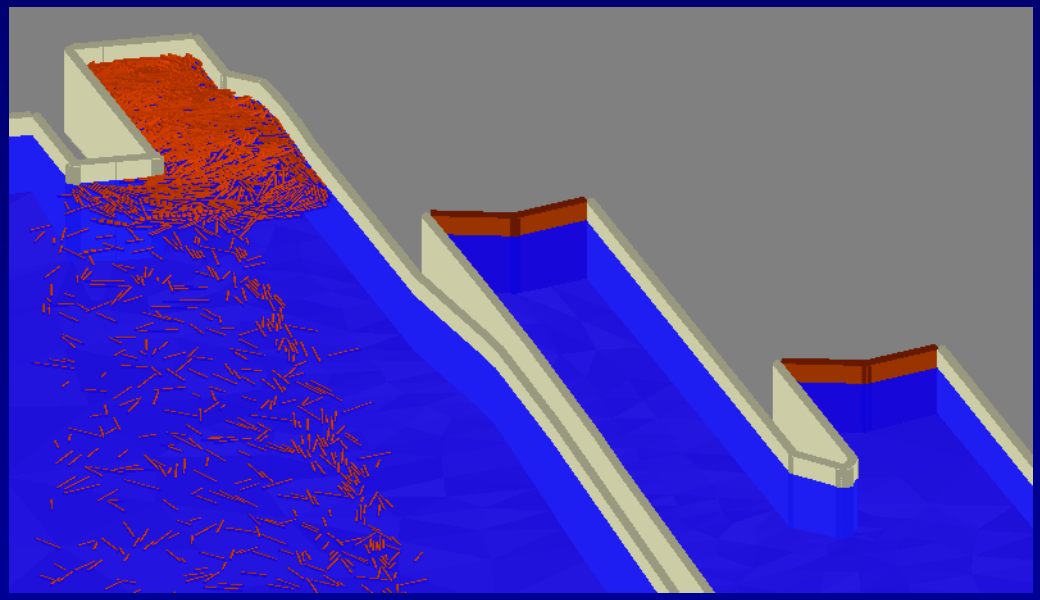
US Army Corps of Engineers®

ERDC
Engineer Research and Development Center
Vicksburg Internet

DEM Simulation of Debris Accumulation at Mon 4 L&D







US Army Corps of Engineers®

ERDC
Engineer Research and Development Center
Vicksburg Internet

DEM/WATER INTERFACE

ICE/DEBRIS

- Water drag on ice/debris
- Ice/debris Velocity
- Spatial distribution of ice/debris layer

WATER (ADH)

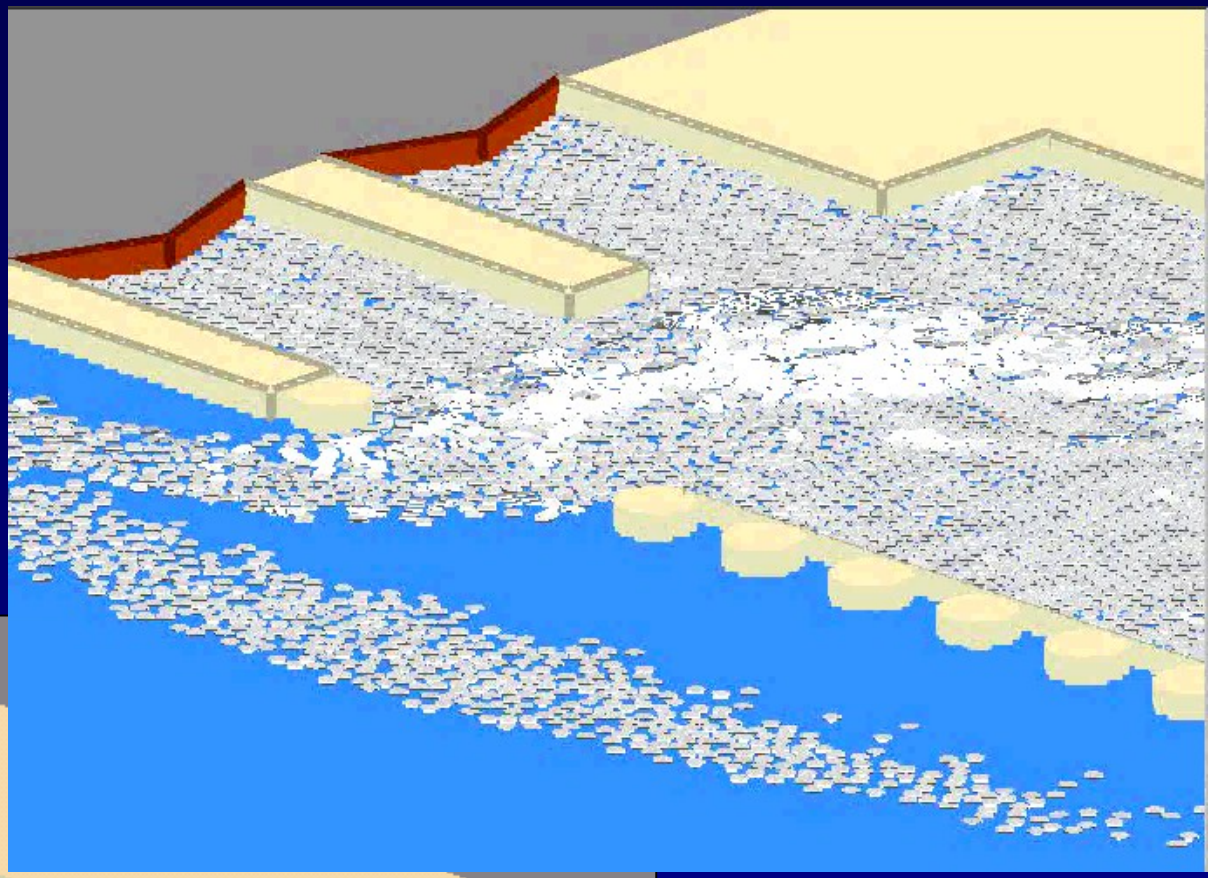
- Water elevation
- Water velocity

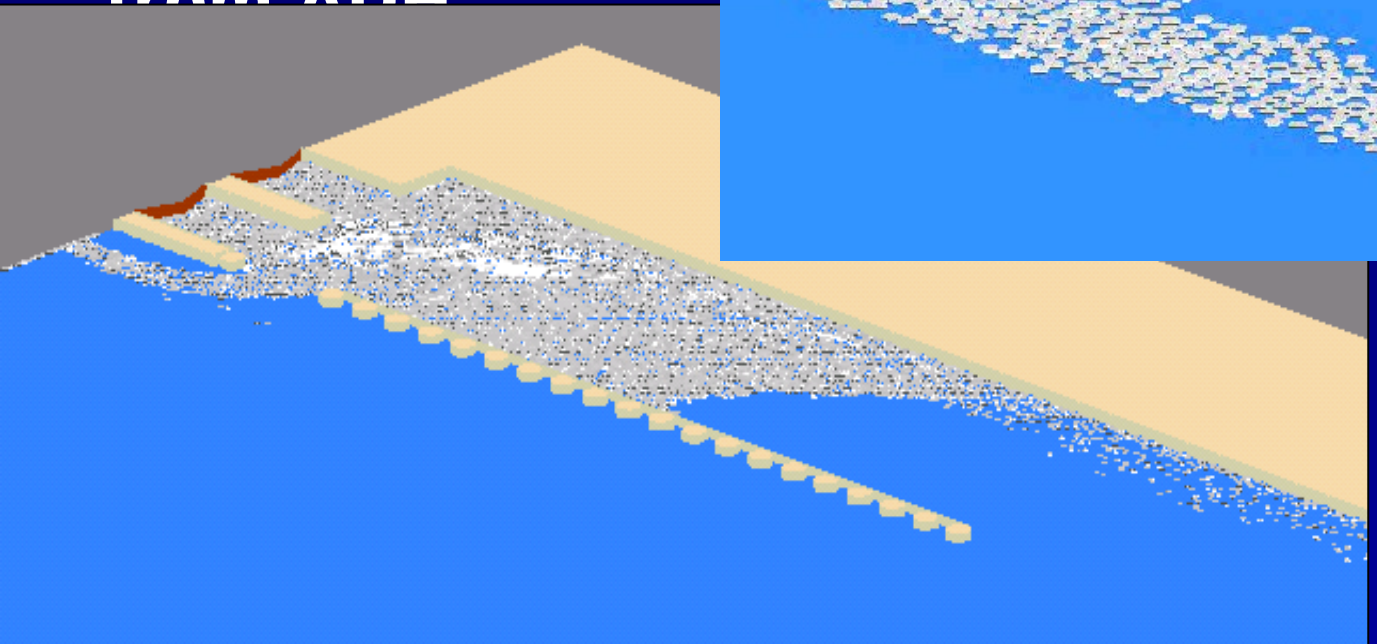
US Army Corps of Engineers®

ERDC

ICE PASSAGE THROUGH A GUARDWALL

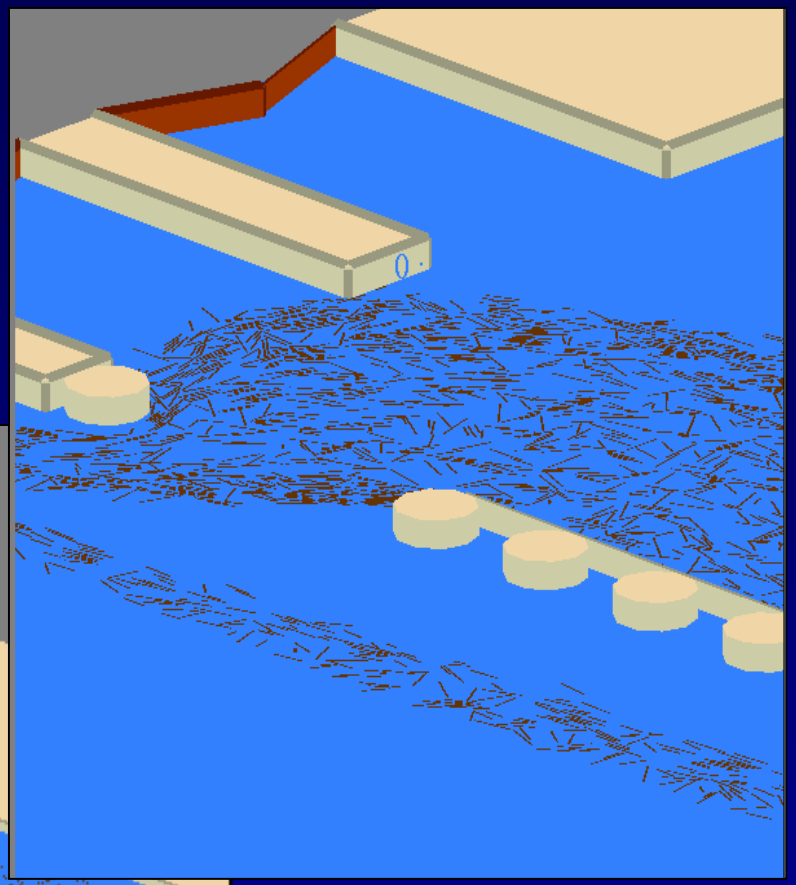
Simulating ice passage through a gap in a guard wall using water velocities from ADH

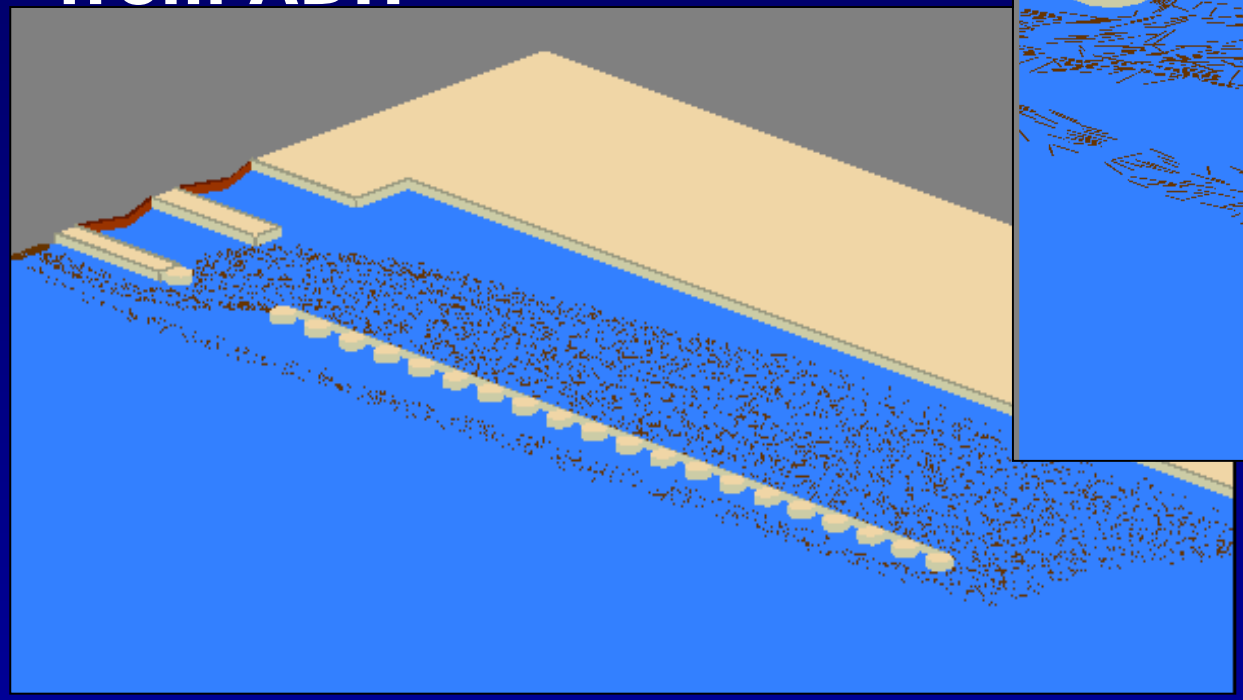




DEBRIS PASSAGE THROUGH A GUARDWALL

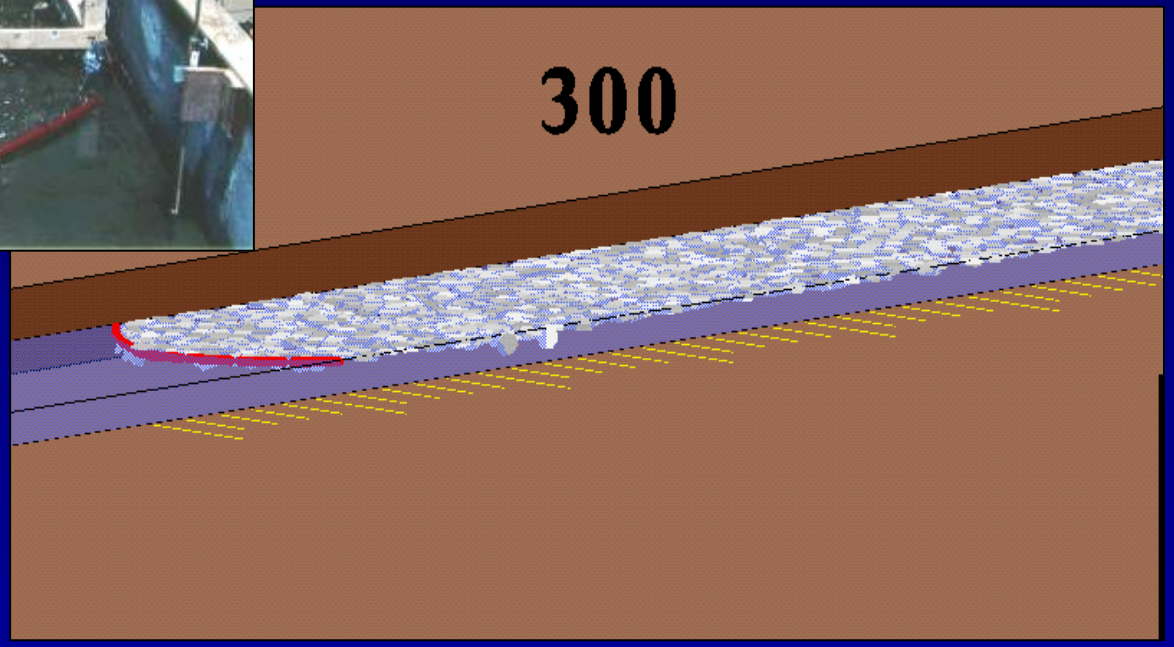
Simulating debris passage through a gap in a guard wall using water velocities from ADH





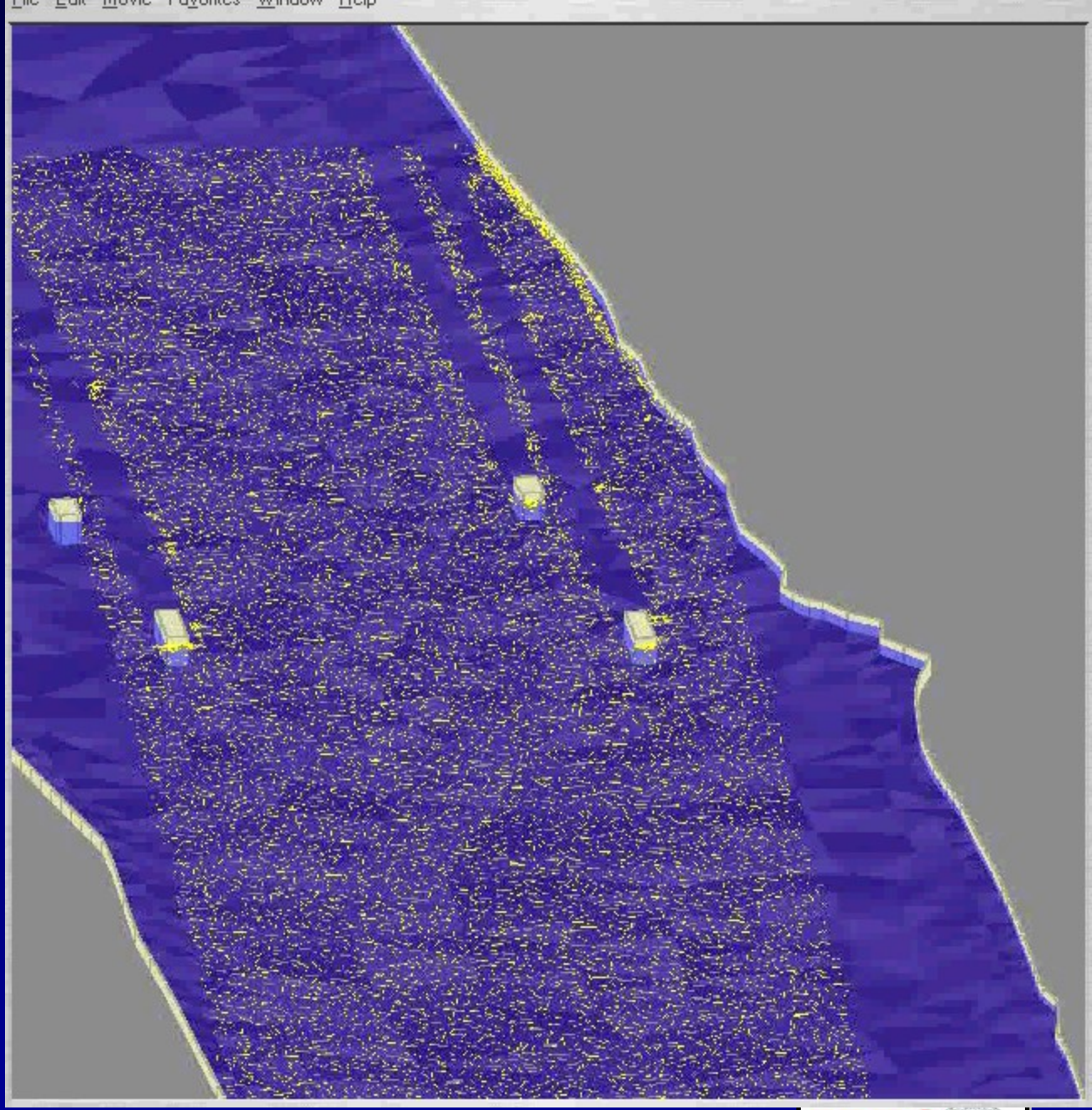
SIMULATION OF ICE BOOM OPERATION

DEM simulation of physical model study used experimental parameters in simulations



Direct comparison of ice retention and forces

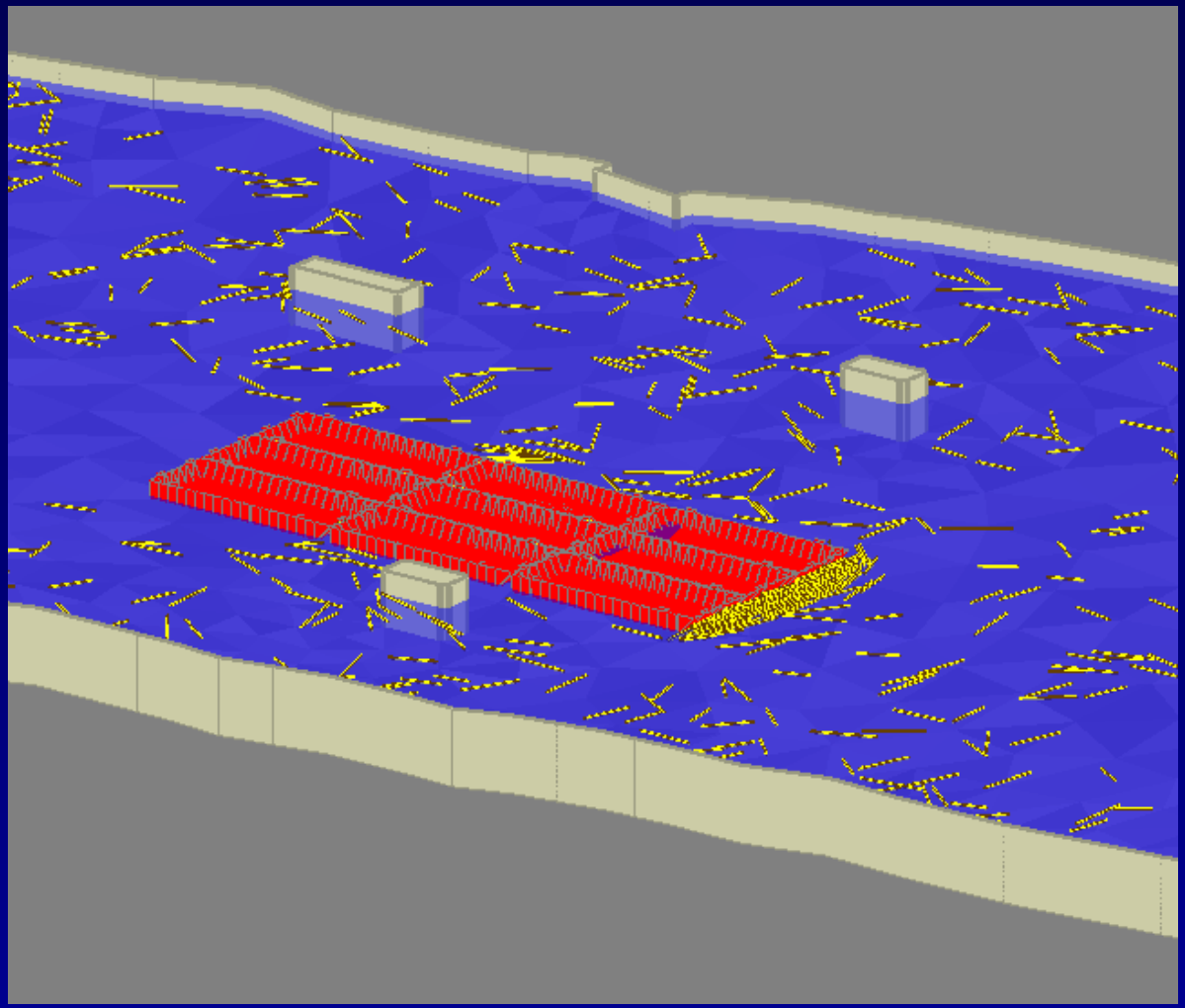
Simulation of Logs and Piers Upstream of Mon 4 L&D



US Army Corps of Engineers®

ERDC

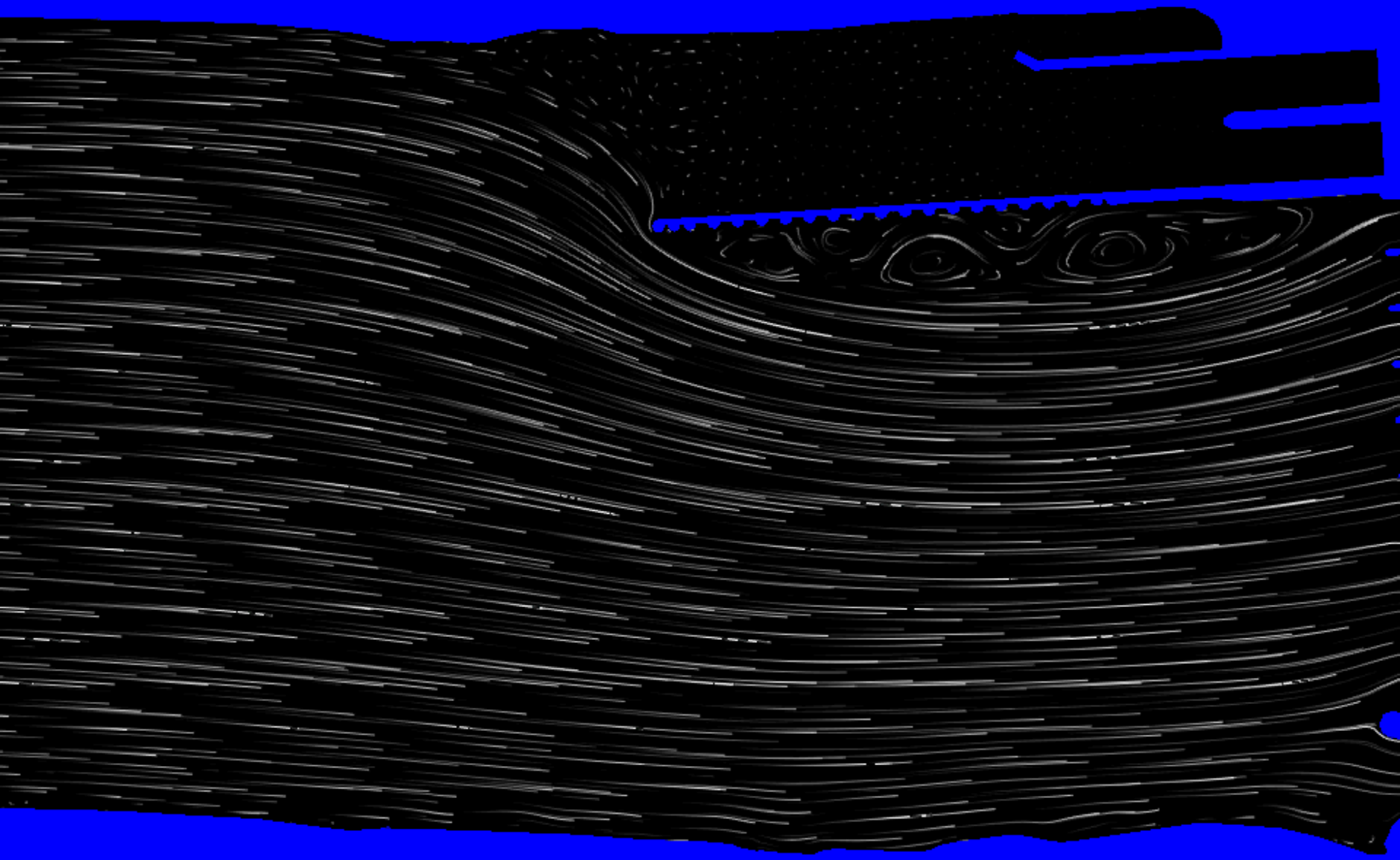
DEM Simulation of Tow, Logs, and Piers Upstream of Mon 4 L&D



US Army Corps of Engineers®

ERDC

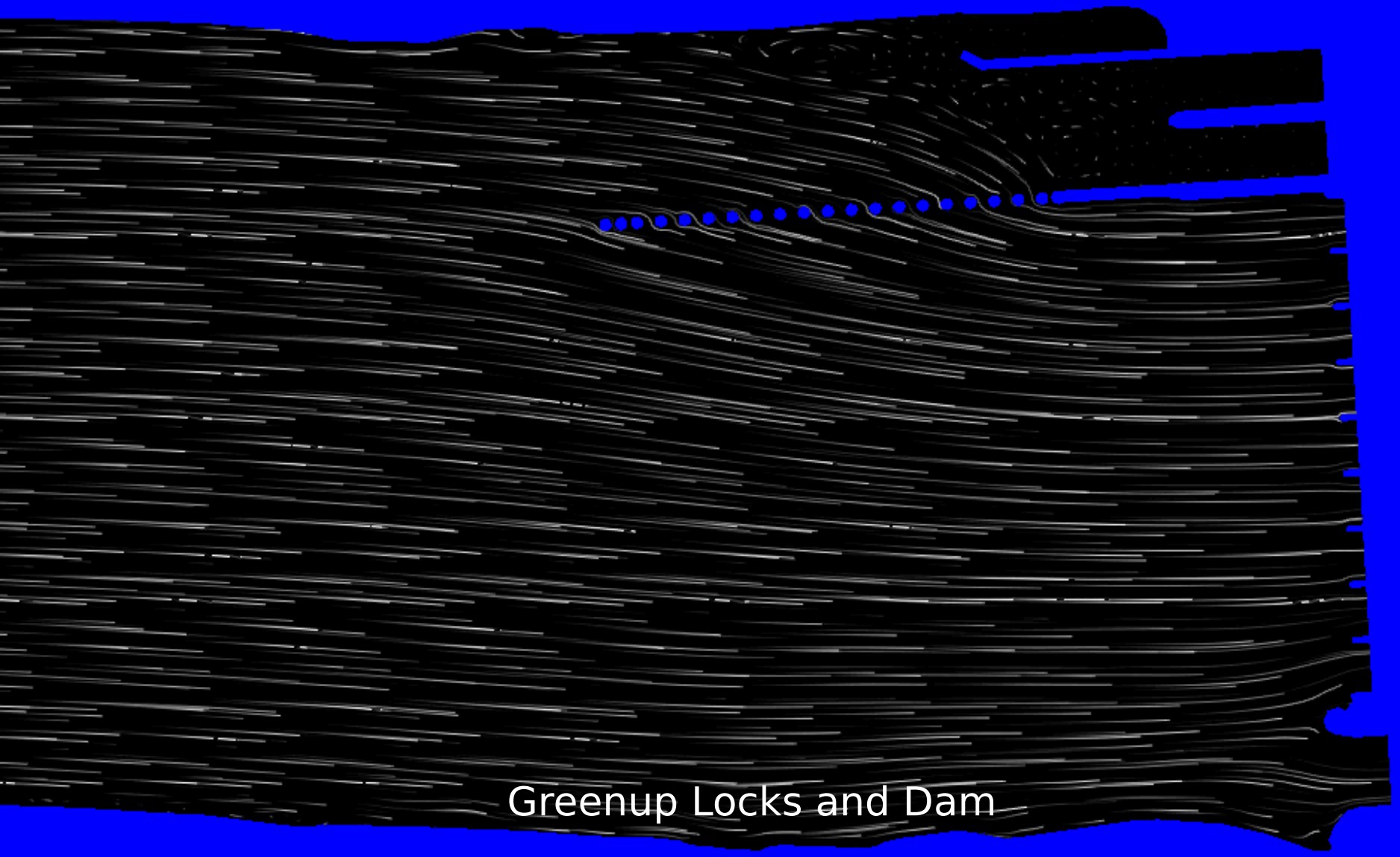
Solid Guard Wall



Greenup Locks and Dam

Ohio River

Ported Guard Wall



Greenup Locks and Dam

Ohio River

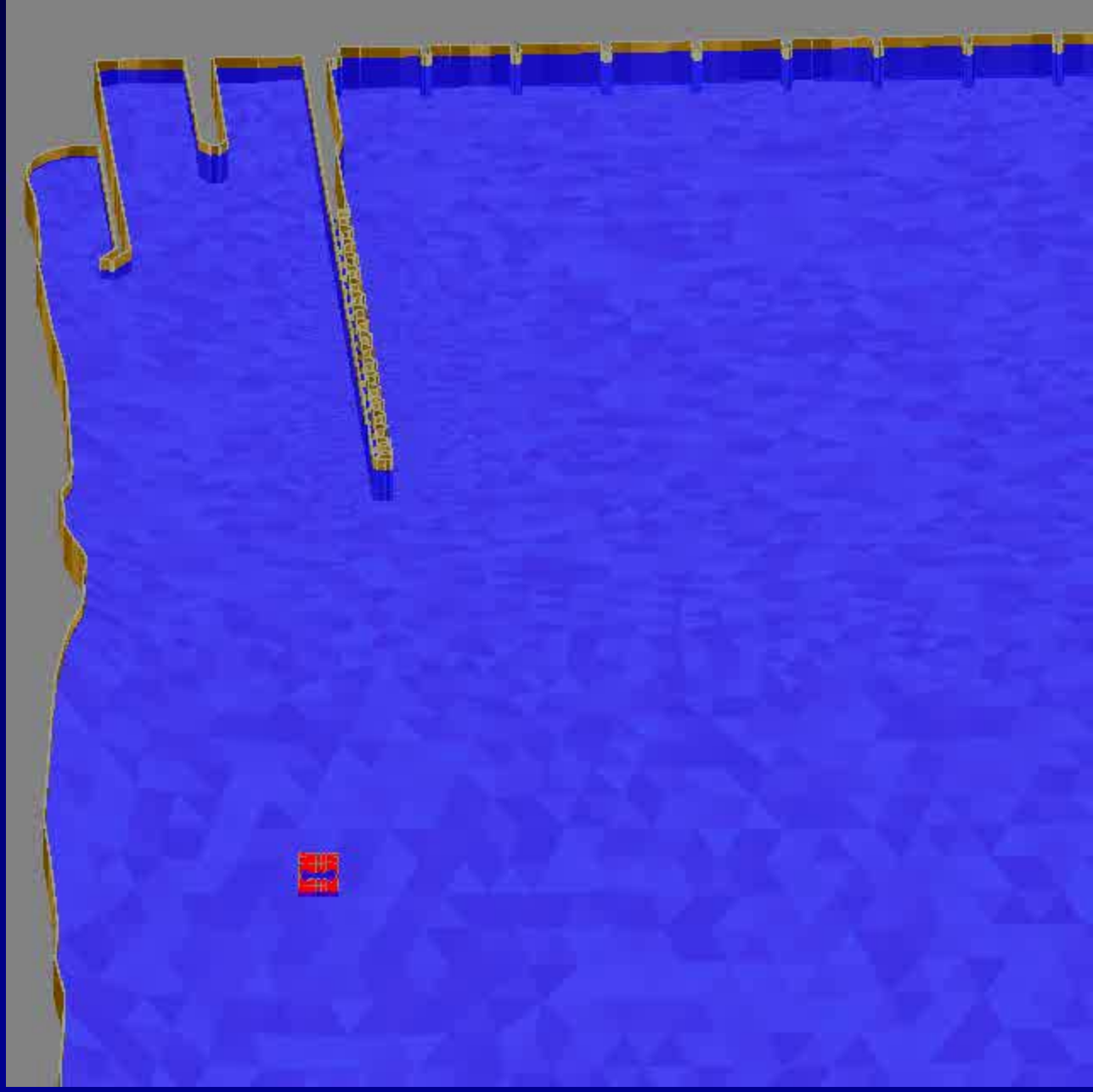
DEM & ADH Models Coupled

Well Designed

Ported Wall

Greenup

Locks & Dam



US Army Corps of Engineers®

ERDC

DEM & ADH
Models Coupled

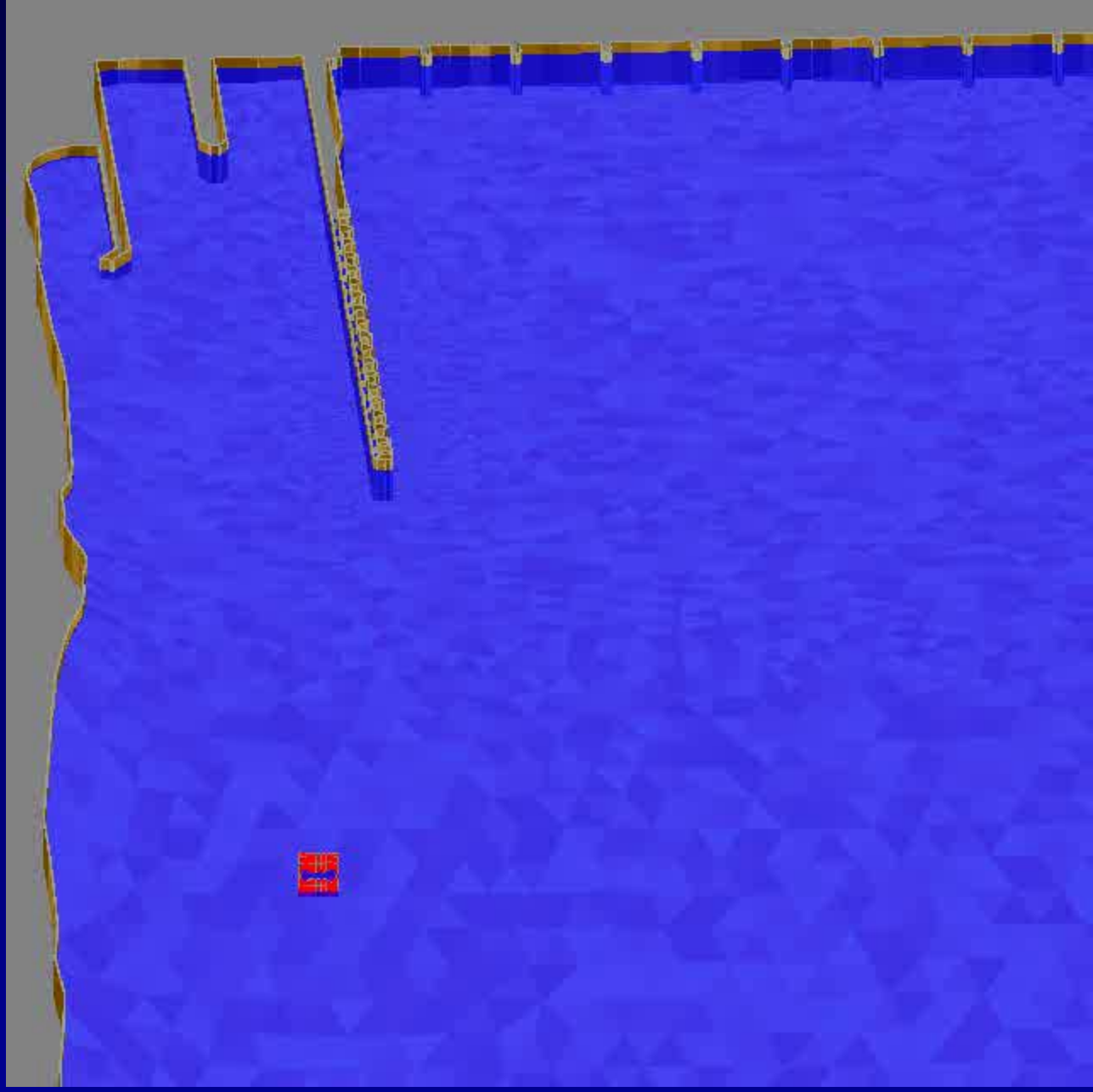
2 Tow Tracks

Ported Wall

& Solid Wall

Greenup

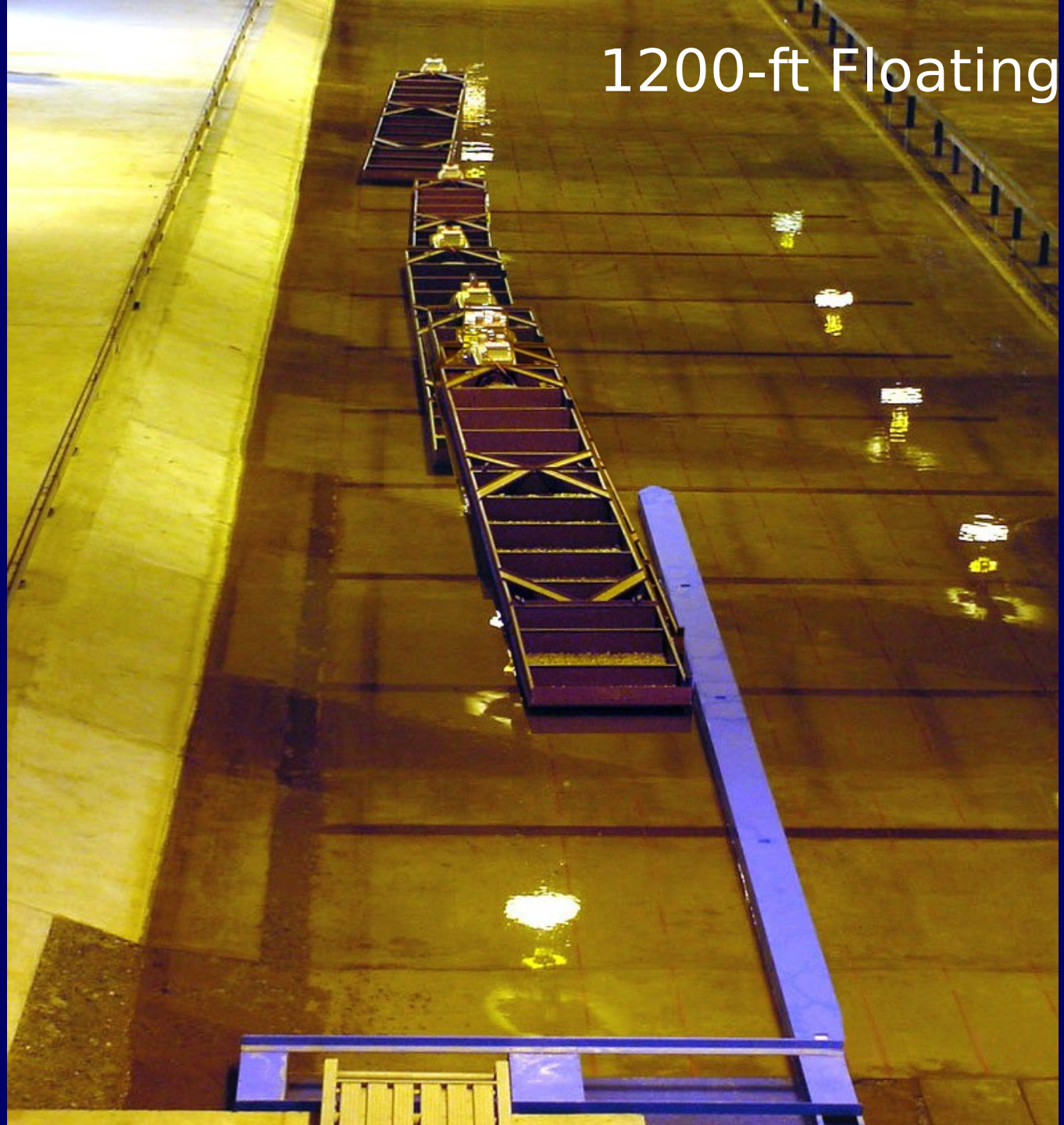
Locks & Dam

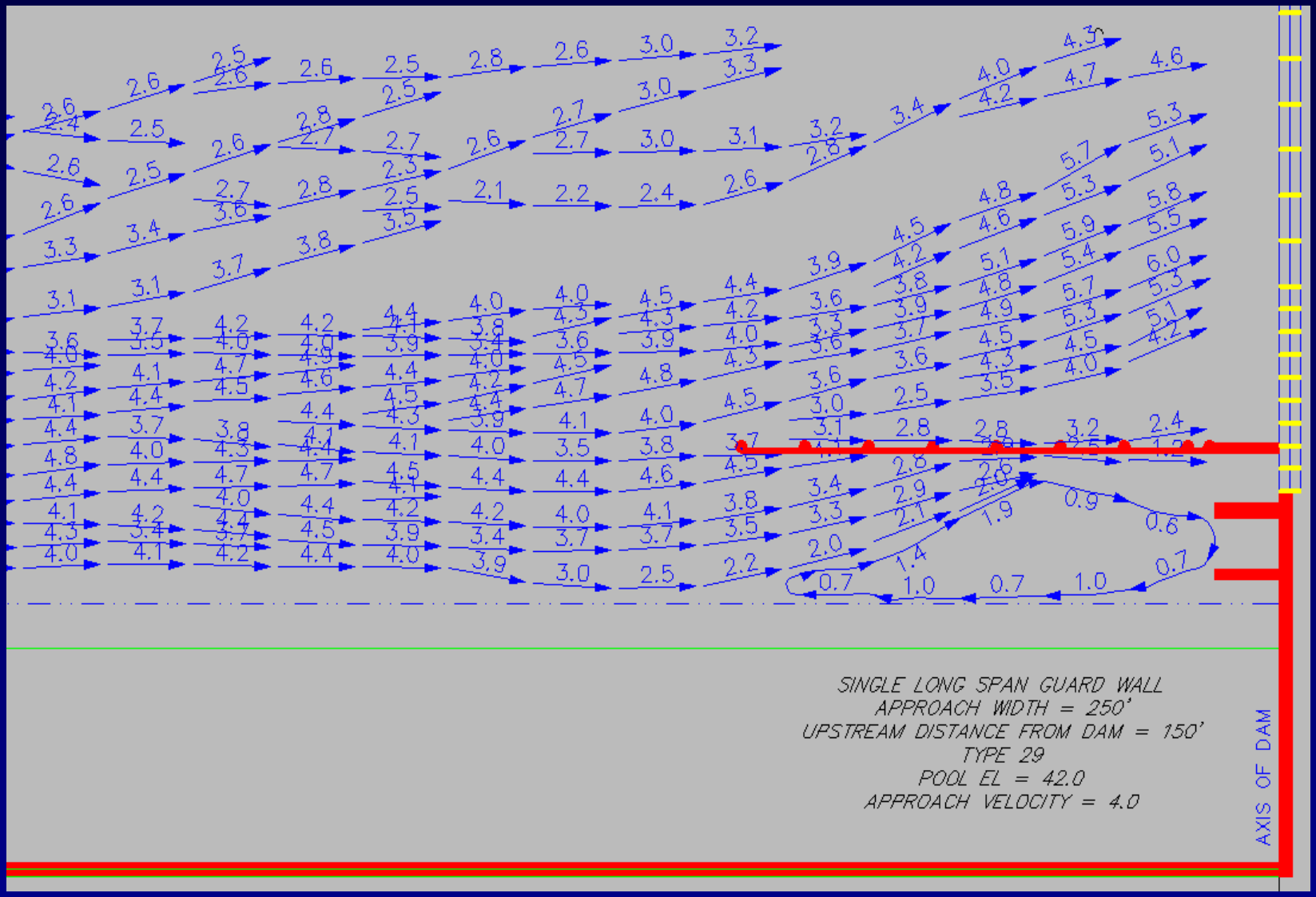


US Army
Corps
of Engineers®

ERDC
Engineer Research and Development Center
Vicksburg Internet

1200-ft Floating Wall

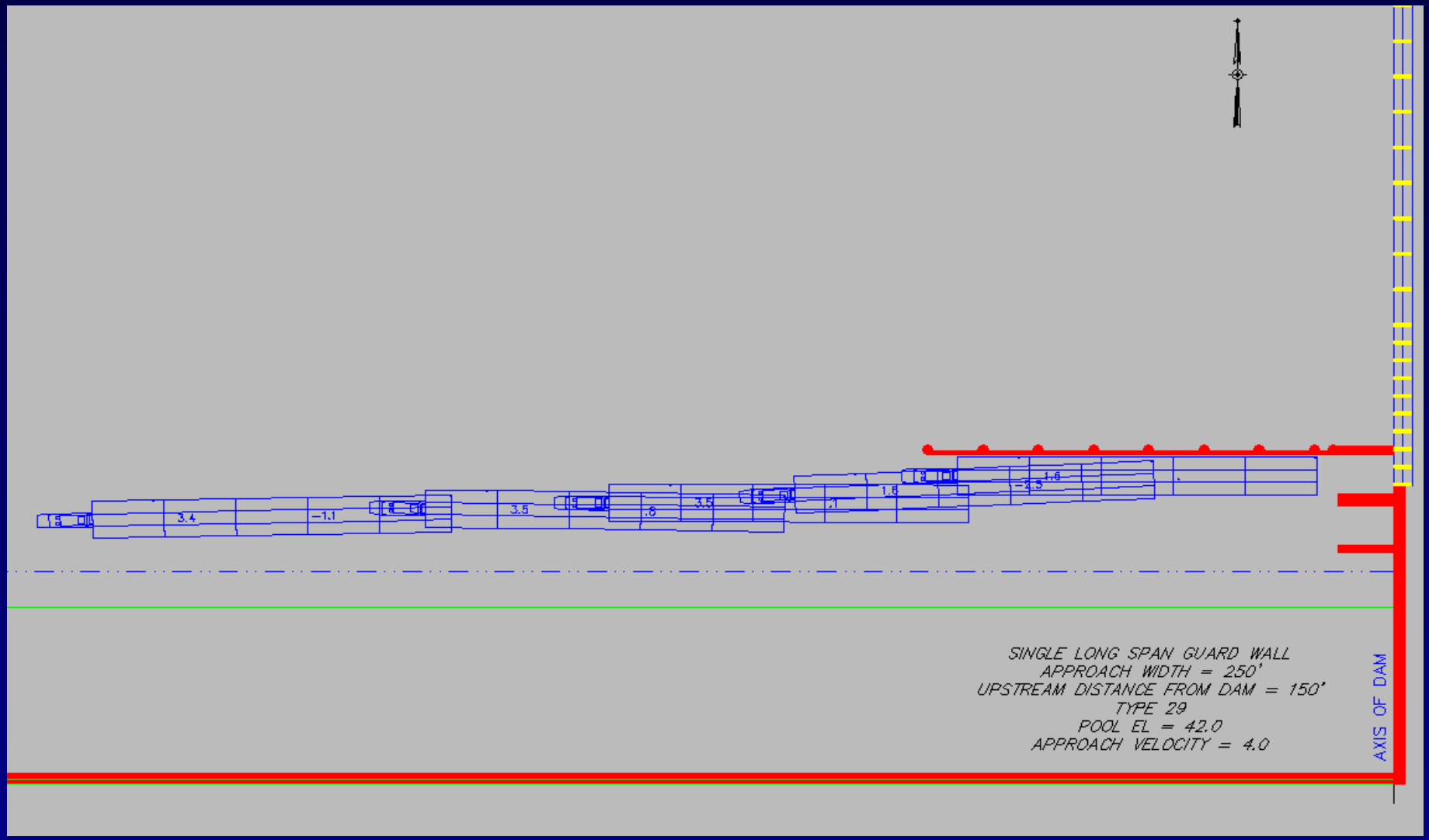



SINGLE LONG SPAN GUARD WALL
APPROACH WIDTH = 250'
UPSTREAM DISTANCE FROM DAM = 150'
TYPE 29
POOL EL = 42.0
APPROACH VELOCITY = 4.0
AXIS OF DAM

Laboratory Results

US Army Corps of Engineers®

ERDC Engineer Research and Development Center Vicksburg Mississippi


SINGLE LONG SPAN GUARD WALL
APPROACH WIDTH = 250'
UPSTREAM DISTANCE FROM DAM = 150'
TYPE 29
POOL EL = 42.0
APPROACH VELOCITY = 4.0
AXIS OF DAM

Tow Approaching a Lock

US Army Corps of Engineers®

ERDC